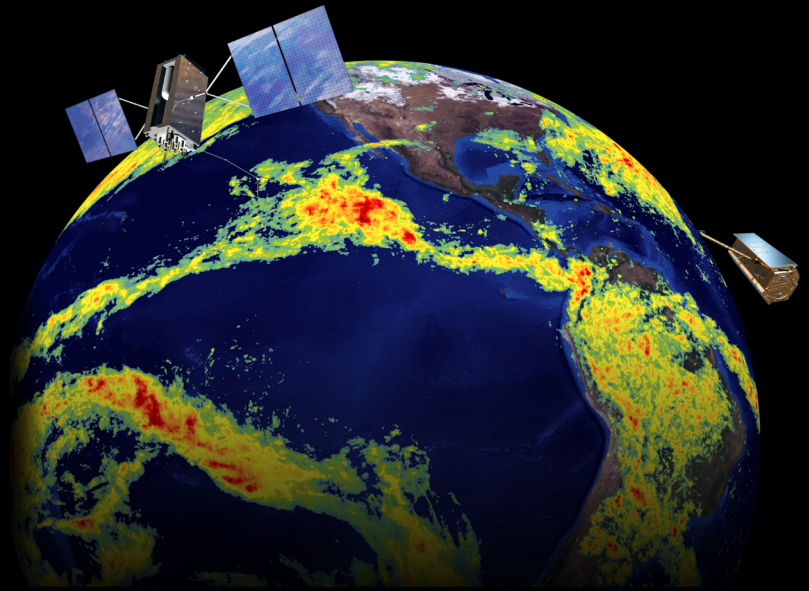
Sensing of Heavy Precipitation aboard the PAZ Satellite: Validation of Polarimetric Radio Occultation Precipitation Observations with GPM Constellation Products



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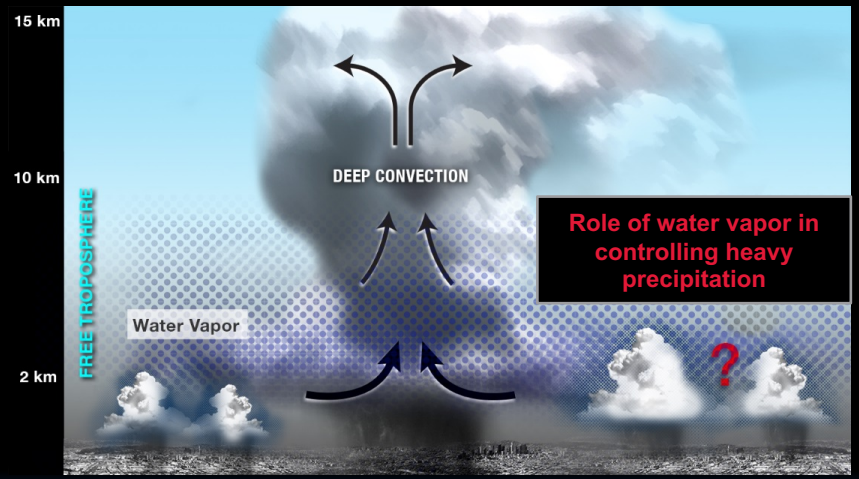
Outline

1. Motivation: Thermodynamics of heavy precipitation
2. Enhanced GPS Radio Occultations for rain detection: **Polarimetric RO**
3. The PAZ mission: proof of concept
4. Results after 6 months of data
    - Validation using GPM constellation products
    - Sensitivity to frozen hydrometeors
5. Summary and Conclusions

Vertical Thermodynamic Structure of Precipitation

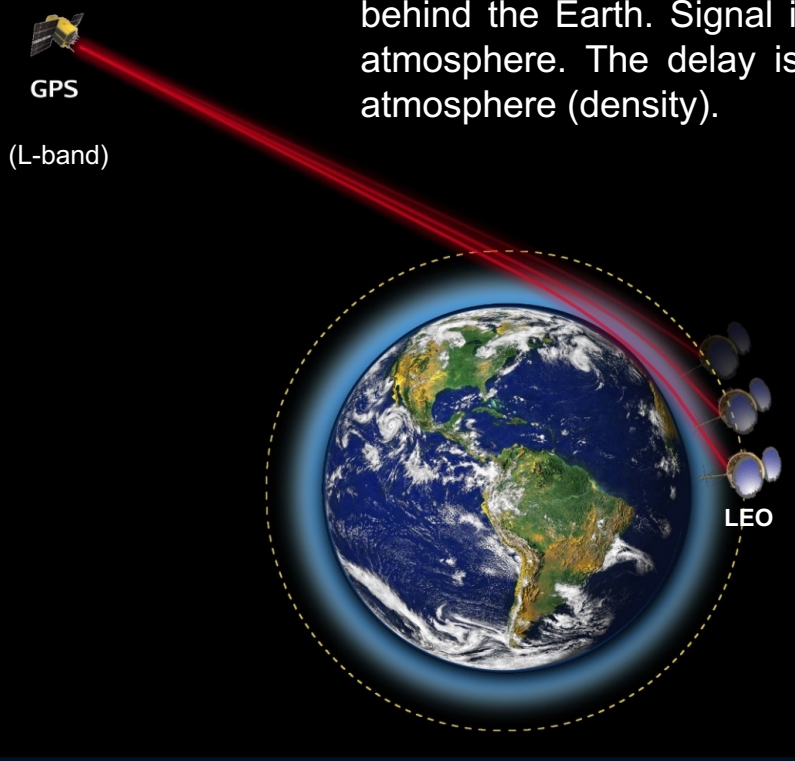
- Convection drives the most intense precipitation events
- There is a lack of thermodynamic observations of such events
- This results in uncertainties in modeling and predicting precipitation



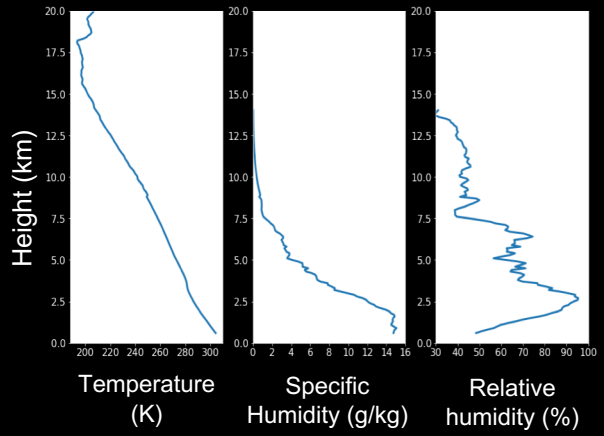
We need more
globally distributed and vertically resolved observations

GPS Radio Occultations

Basics of the concept: A LEO tracks the signal from a GPS while it is occulting behind the Earth. Signal is delayed and bent when crosses different layers of the atmosphere. The delay is associated with changes in the refractive index of the atmosphere (density).



Excess Phase → Bending angle profile → Refractivity profile → *T, q* profiles

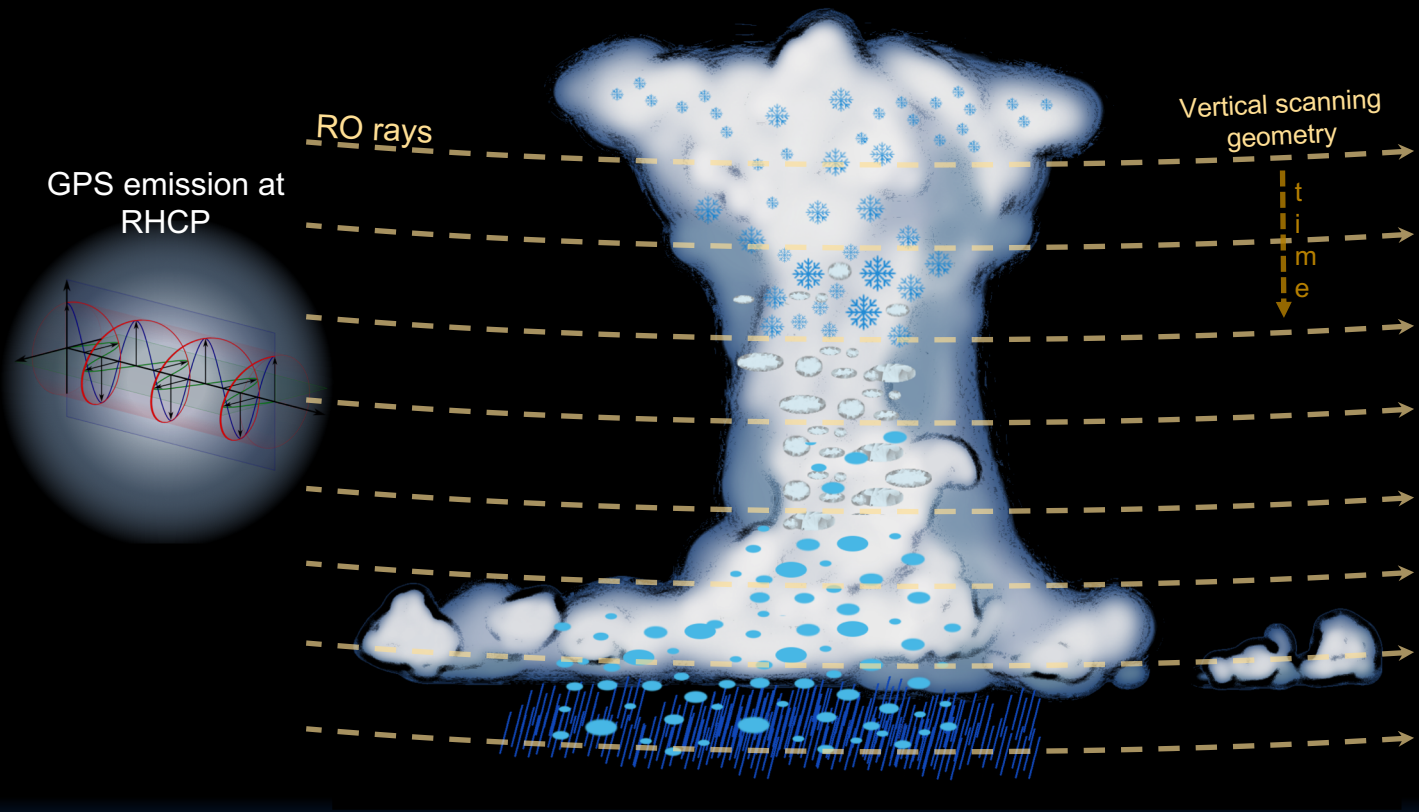


Characteristics of RO observations:

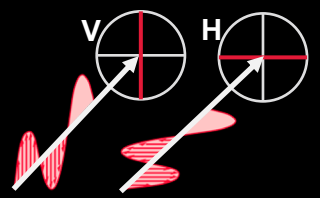
- Global
- High vertical resolution
- No calibration required
- Over all surfaces
- Through all clouds

- Horizontal res. ~150 km

Polarimetric Radio Occultations (PRO)



LEO reception at two linear orthogonal polarizations H & V



In the presence of asymmetric hydrometeors:

$\Phi_H - \Phi_V > 0$

Vertical information of **precipitation**

+

Thermodynamic profiles

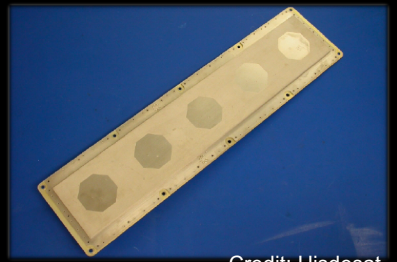
Radio Occultations and Heavy Precipitation with PAZ (ROH-PAZ)

- Proof of concept mission on the Spanish PAZ satellite
- Main PAZ payload: SAR
- PAZ launched **Feb 22, 2018**, from VAFB
- Sun-synchronous dusk/dawn polar orbit
- **Polarimetric experiment** activated on May 10, 2018

PAZ artistic view

Credit: Hisdesat

PAZ Pol RO antenna



Credit: Hisdesat

PAZ satellite deployment

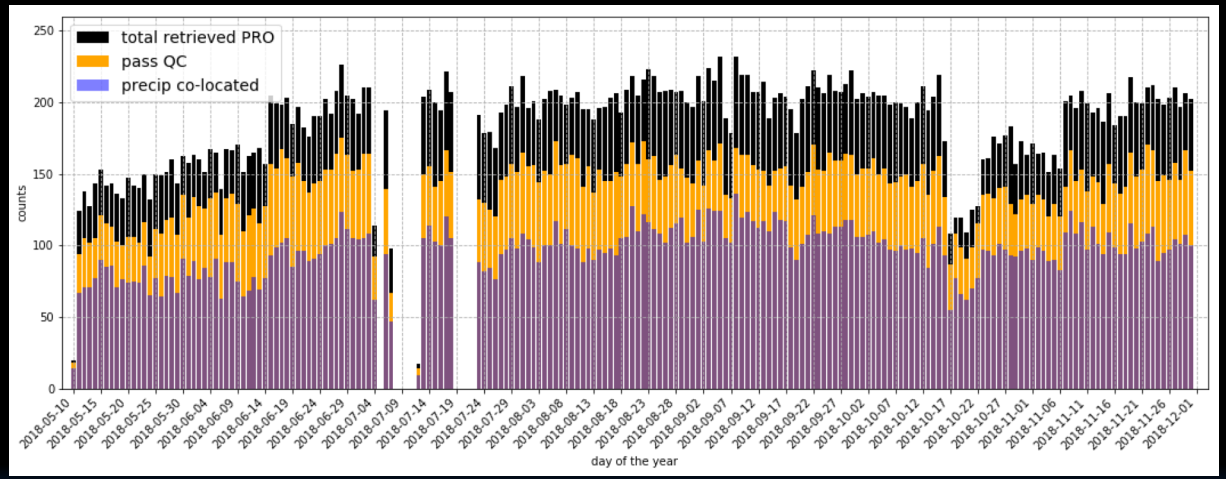
Credit: SpaceX

Credit: SpaceX

Status of the ROHP-PAZ mission

- Thermodynamic profiles: nominal quality
- PoI RO data: activated May 10, 2018. Commissioning phase on-going.

RO profiles: 36,241	successful QC: 28,559	QC + precipitation co-location: 19,892



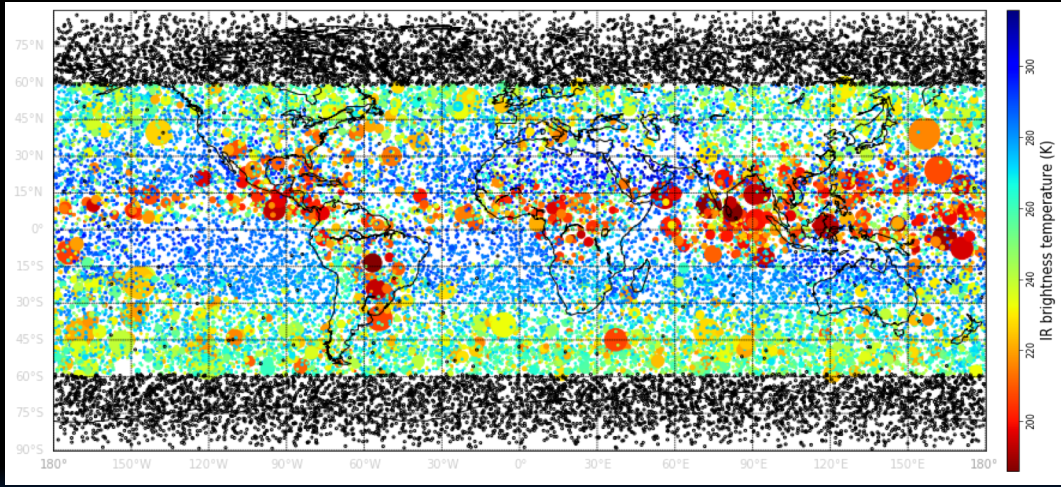
Validation of ROHP-PAZ observations: 2D co-locations

GPM **I**ntegrated **M**ulti-satellit**E** **R**etrievals (IMERG) :

- 2D surface precipitation
- Globally distributed within ± 60 Lat
- 0.1 deg spatial resolution
- 30 minutes time resolution

NCEP/CPC IR brightness temperature :

- 30 min time resolution; 0.03 deg spatial res
- Globally distributed within ± 60 Lat



Validation of ROHP-PAZ observations: 2D co-locations

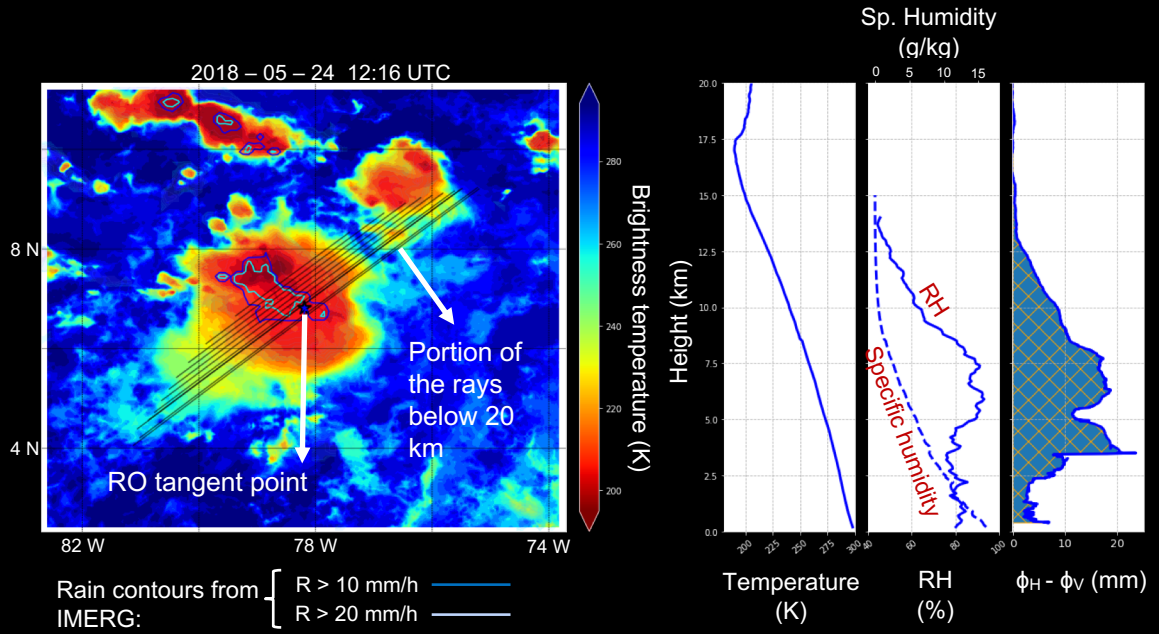
Example of a 2D co-located observation:

IR brightness temperature shows a developed deep convective cloud

IMERG precipitation indicate large Rain Rates close to the surface

PRO observation exhibits a large positive $\Delta\phi_{H\text{-}V}$

Coincident thermodynamics is also provided



Validation of ROHP-PAZ observations: 2D co-locations

Statistical results:

Rain free events:

- Mean -> 0
- Dispersion: < 2° @ 4km
- Dispersion: < 4° @ 2km

Rainy events:

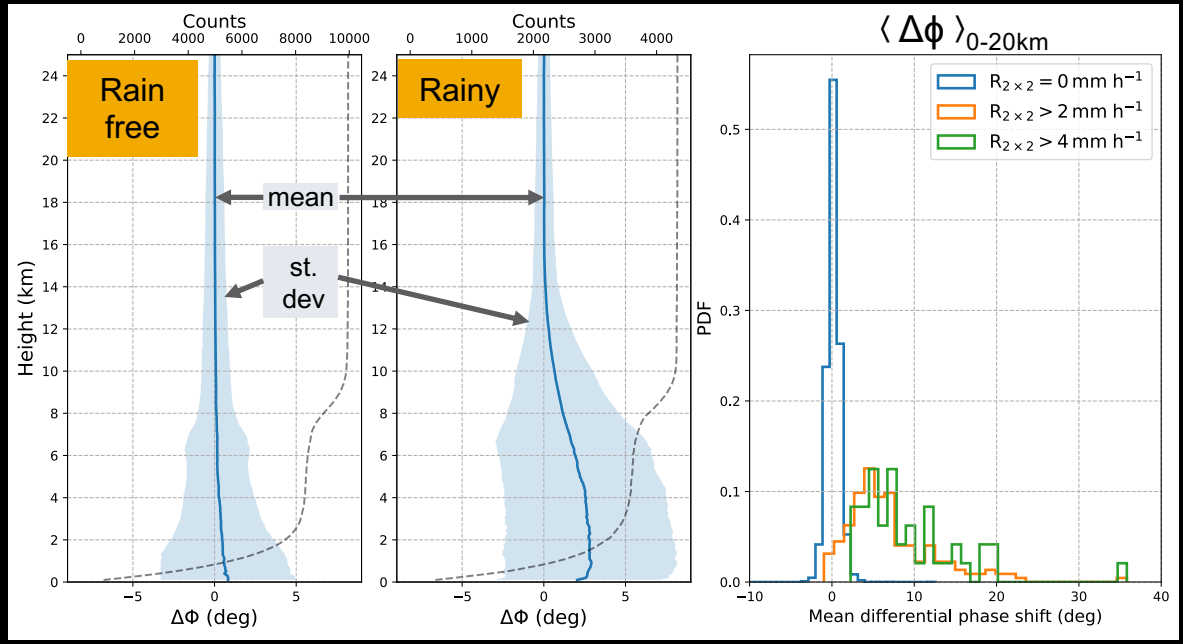
- Positive mean < 10km
- Mean > rain free dispersion

$\langle \Delta\phi \rangle_{0\text{-}20km}$:

- No rain: centered at 0°
- 99.97% R=0 below 4°
- < 1% false positives

All the profiles grouped by precipitation and no-precipitation

Mean of each individual profile grouped by different R



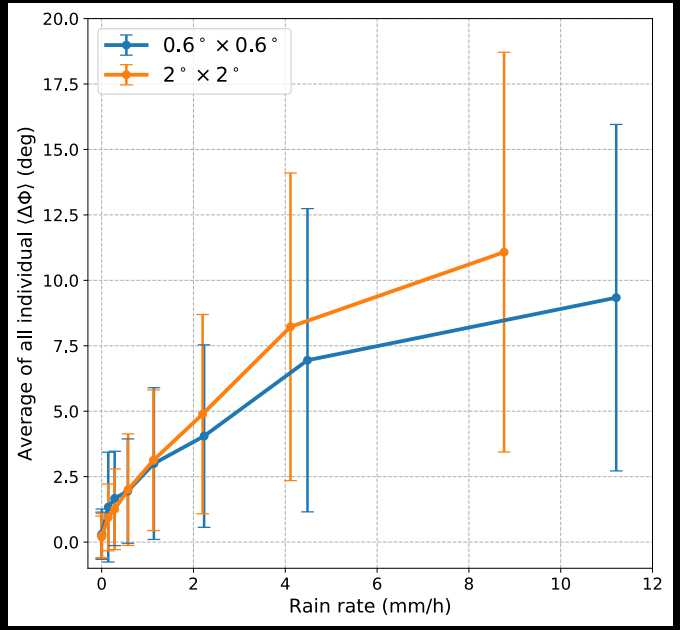
Cardellach et al. 2018, Geophysical Research Letters DOI: 10.1029/2018GL080412

Validation of ROHP-PAZ observations: 2D co-locations

Statistical results:

$\langle \Delta\phi \rangle_{0\text{-}20km}$ is sensitive to precipitation

$\langle \Delta\phi \rangle_{0\text{-}20km}$ as a function of rain rate



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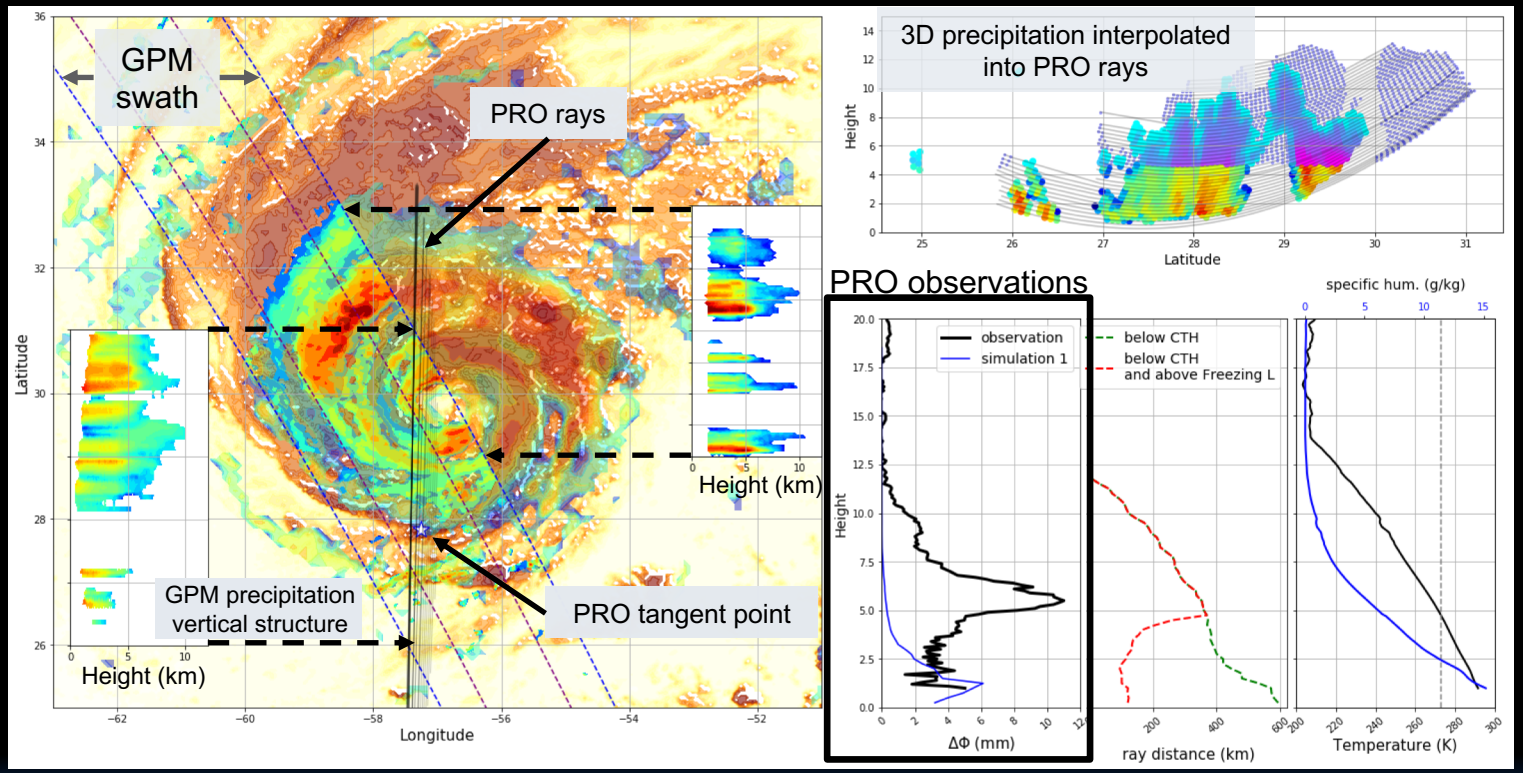
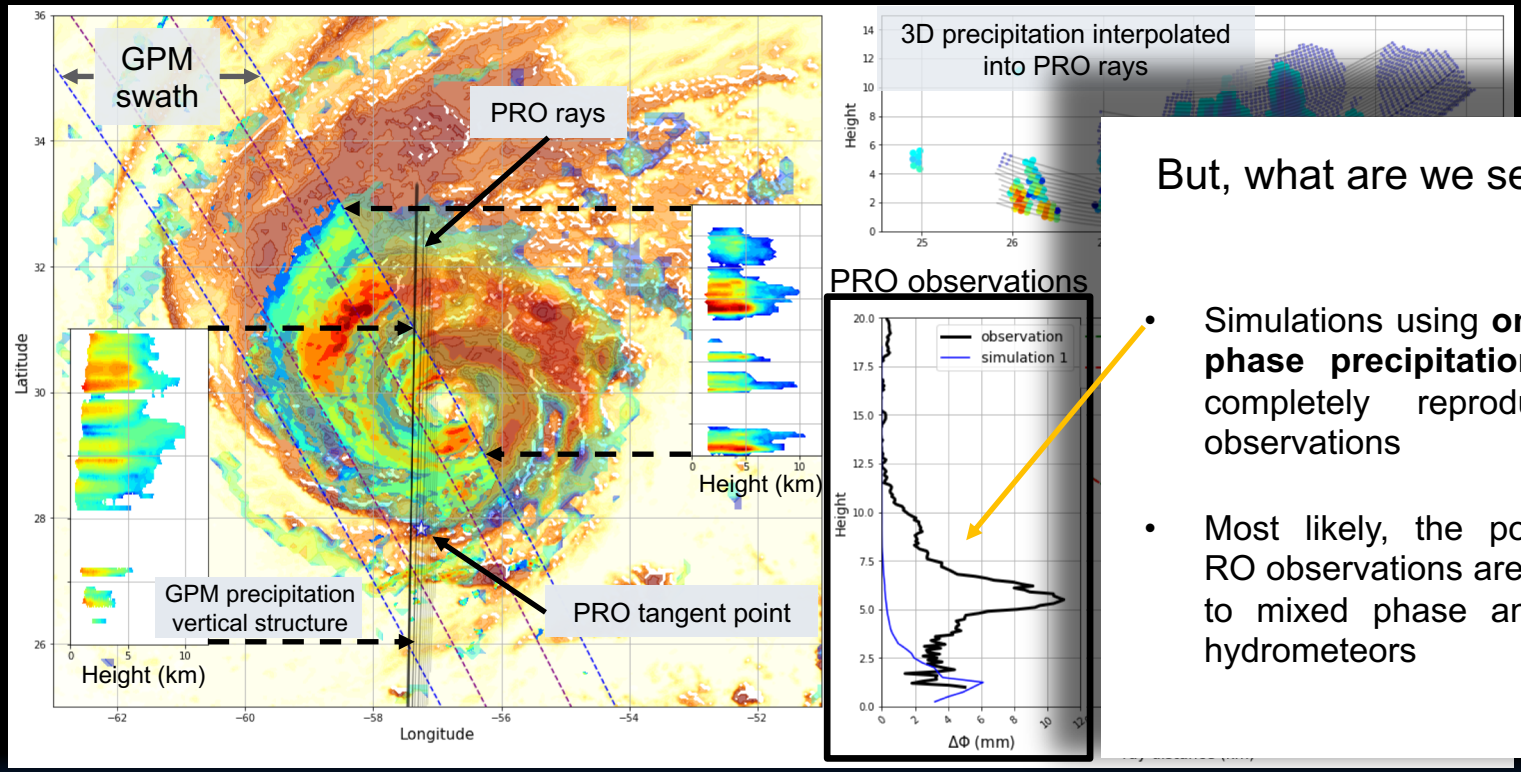
Validation of ROHP-PAZ observations: 3D co-locations

Hurricane Leslie



Validation of ROHP-PAZ observations: 3D co-locations

Hurricane Leslie



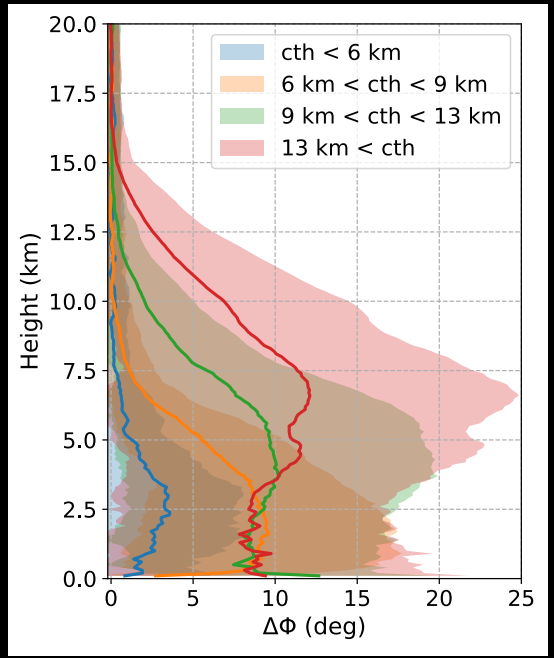
But, what are we sensing?

- Simulations using **only liquid phase precipitation** cannot completely reproduce the observations
- Most likely, the polarimetric RO observations are sensitive to mixed phase and frozen hydrometeors

Validation of ROHP-PAZ observations

But, what are we sensing?

- Using geostationary infrared brightness temperature, we infer (approximately) the Cloud Top Height (CTH).
- Grouping the observations by CTH, we can see the changes in the vertical structure of PRO observations
- **PRO observations are sensitive to mixed phase and frozen hydrometeors**



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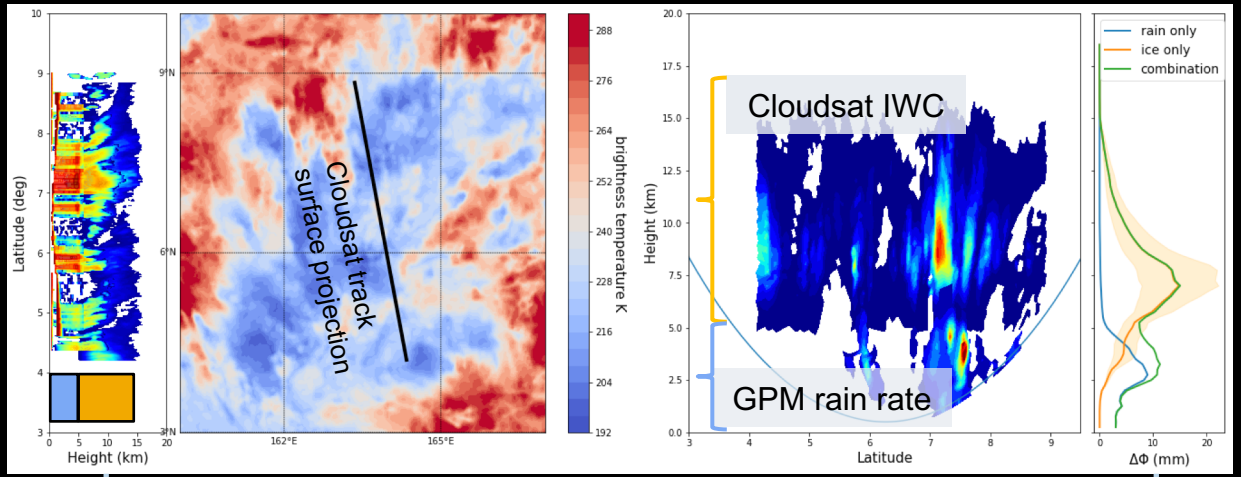
Validation of ROHP-PAZ observations

But, what are we sensing?

GPM – CloudSat coincidence



GPM and Cloudsat reflectivity
GPM : below Freezing Level
Cloudsat: above Freezing Level

Simulations of PRO observations using rain only (GPM provided), Ice only (cloudsat provided), and the sum of both

PRO observations can be explained including the frozen particles (mixed phase not accounted for, yet) that GPM radar cannot observe, but CloudSat can.

Summary and Conclusions

- ROHP – PAZ experiment: first time ever GPS Radio Occultations are acquired at two polarizations
- Polarimetric Radio Occultations observations are sensitive to precipitation
- PRO observations are also sensitive to other hydrometeors: liquid phase, mixed phase and frozen particles
- PRO can provide information on the vertical structure of precipitating systems
- Unique observing system able to provide, simultaneously, vertical thermodynamic and precipitation profiles from space under all weather conditions

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